Critical Success Factors for Implementing Quality Engineering Tools and Techniques in Malaysian's and Indonesian's Automotive Industries: An Exploratory Study

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Abstract— **Organizations regardless of their size are facing increasing competition from global markets. Quality engineering (QE) tools and techniques are a cornerstone of continuous improvement. They have both specialist and universal applications. If they are not used in a systematic manner, quality improvements are likely to be random and spontaneous rather than comprehensive. The need for an improved understanding of the critical factors for effective and successful QE implementation is becoming more important. However it is the variety and by their nature complexity, that often can create difficulties in their selection, application and effective use. This paper is exploratory paper which explores automotive industries expert's opinion in Malaysia and Indonesia to investigate the difficulties associated with the use of QE tools and techniques, critical factors for effective QE practices and specific issues related to QE implementation. For the purpose, the Delphic Hierarchy Process (DHP) approach was employed as the methodology to evaluate the critical success factors for effective and successful implementation of QE tools and techniques in Malaysian's and Indonesian's automotive industries. As a result from exploratory study, a conceptual model using DHP approach is established. The DHP approach is a combination of the Delphi method and the analytical hierarchy process (AHP). The DHP can benefit from both a strong and widely used Delphi method and a powerful mathematical model, the AHP.**

Keywords – Quality engineering, critical success factors, DHP, Automotive industry, Malaysia and Indonesia

I. Introduction

Montgomery [1] defined QE as the set of operational, managerial and engineering activities that company uses to ensure that the quality characteristics of a product are at nominal or required levels. Krishnamoorthi [2] also defined the term QE as the discipline that includes the technical methods, management and costing approaches, statistical problem-solving tools, training and motivational methods, computer information systems, and all the sciences behind them that are needed for designing, producing and delivering products and services to satisfy customer needs.

The American Society for Quality Control (ASQC)'s definition of the QE body of knowledge includes the following major elements i.e.: fundamental concepts of probability, statistical quality control (QC) and design of experiment; quality planning and management, and product liability; metrology, inspection and testing; quality cost analysis; quality auditing; reliability, maintainability and product safety; quality information systems; and motivation and human factors [3].

A large number of statistical tools and method are applied in manufacturing and service firms. Quantifying and improving quality requires the use of specific methods or tools [4]. Tools are not to solve the existing or would be problems, but as means of identifying the problems or strengths in specific terms through systematic manners and the users must understand the applicability of a particular tool before being applied [5]. A technique on the other hand, has a wider application than a tool and is understood as a set of tools. This often results in a need for more thought, skill, and training to use techniques effectively. Techniques can be thought of as a collection of tools which are necessary for the effective use of the technique [6]. For example, statistical process control (SPC) employs a variety of tools such as charts, graph, and histogram. Some of techniques are: SPC, benchmarking, Quality Function Deployment (QFD), Failure Mode and Effect Analysis (FMEA), Design of Experiments (DoE), etc. Some of QE techniques are suitably applied at the design stage such as QFD, DoE, etc and the other are suitably applied at the production stage such as, SPC.

The aim of this paper is to explore automotive industries expert's opinion in Malaysia and Indonesia to investigate the difficulties associated with the use of QE tools and techniques, critical factors for effective QE practices and specific issues related to QE implementation with a new methodology for this research area, the Delphic Hierarchy Process (DHP). Combining the Delphi technique with the AHP was first proposed by Khorramshahgol and Moustakis [7] and named the DHP. The following section discusses the success factors implementing QE, detailed procedures of the DHP followed by the Delphi technique and result from the first round of the Delphi method.

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II. SUCCESS FACTORS FOR IMPLEMENTING QE

The recent study by Putri and Yusof [8] summarized that studies on quality practices found in the literature in Malaysia and Indonesia had focused on total quality management (TQM) and implementation of ISO 9000, technological learning, and the research conducted in manufacturing organizations in general. The review shows that there are limited studies on QE conducted in Malaysia and Indonesia and mainly focused in manufacturing organizations leaving much room for further studies to be made in the automotive industries.

The main motivating factor for conducting this study was to find out the differences between Malaysian and Indonesian automotive industries on QE tools and techniques practices. This study will be complementing the research conducted by Zakuan and Yusof [9]. Thus, to survive in a competitive market place, quality practices implementation is one of the key issues that can help align organization's to stay competitive. Besides that, based on current situation, comparative study among ASEAN, especially Indonesia, is gives a good opportunity that could provide an overall perspective and understanding of the commonalities and differences of critical success factors (CSFs) for effective QE tools and techniques practices in Malaysia and Indonesia context to gain insights in the status of these practices.

It is strongly believed that the findings of this study will be suitable, effective and help local car manufacturers and suppliers in their effort to become more effective and competitive. Else, research on quality management practices in the ASEAN region will add to the total knowledge of quality management and could help to develop a unique model for quality management.

For the purpose of this research and within the QE context, CSFs for QE implementation will be defined as "factors needed to ensure an effectiveness of QE implementation." As can be seen, the CSFs for QE implementation are very similar to the CSFs for total quality management (TQM) implementation due to its close relationship with TQM program. Within the area of TQM a wide range of tools are used, the development of organizational tools and concepts and the application of quality tools throughout an organization (i.e. also in other areas than production and design). The proposed critical factors for effective implementation of quality engineering for Malaysia's and Indonesia's automotive industries are summarized in Table 1. There are seven major factors are identified and named as criteria. For each criterion a set of specific sub-factors are identified. This comprehensive set of criteria and sub-factors is used in the Delphi hierarchy process technique described in the next section. The work reported in this paper focuses on understanding the factors that are motivating and influencing effectiveness of QE implementation, and hence a research tool Delphic hierarchy process that combined Delphi approach and analytic hierarchy process approach. The Delphi approach – capable of eliciting expert information is used. Delphi is a technique used for gathering and developing opinion from a panel of experts. Additionally by using the AHP, it is believed to be an efficient way to deal with complex systems, and priorities for alternatives can be developed based on the decision maker's judgments throughout a system. The complex problem can be represented as a hierarchy. A hierarchy is an effective approach to tackle unstructured problems because it is efficient in organizing the structure for a system as well as controlling and passing information down the system [10].

Table 1 Summary of major criteria and sub factors/sub criteria affecting effectiveness of QE implementation [11].

Major factors (criteria)	Sub-factors (sub-criteria)
Management responsibility	Strategic quality planning/quality policy; the role of divisional top management; top management commitment/support; internal stakeholders' involvement (middle management involvement)
Resource management	Technology-and production related resources; financial-related resources; information and communication-related resources
People management	Employee involvement/empowerment; education and training; teamwork and cooperation; work environment culture
Quality in design and process	Process management/operating procedures; role of quality department; product design; process analysis and improvement; applied quality tools and techniques
Measurement, analysis and feedback	Quality measurement, feedback and benchmarking; continuous improvement; performance measurement: external and internal; quality data and reporting; communication to improve quality; recognition and rewards; quality systems
Supplier management	Supplier quality management/supplier chain management; contact with supplier and professional associates
Customer focus	Customer involvement/satisfaction/orientation; customer driven processes

All critical success factors (CSFs) for effective implementation of QE tools and techniques are based on extensive literature review as shown in Table 1. Putri and Yusof [12] have proposed the hierarchy structure of the CSFs for effective and successful QE tools and techniques implementation which in this paper it will be validate through Delphic technique. The Delphic hierarchy process is described in details next.

III. THE DELPHIC HIERARCHY PROCESS

The DHP is a combination of the Delphi technique and the AHP. The DHP can benefit from both a strong and widely used Delphi technique and a powerful mathematical model, the AHP [13]. Five steps for the DHP suggested by Khorramshahgol and Moustakis [7] are: 1) form a monitoring team to conduct the Delphi inquiry; 2) select the Delphi expert group; 3) perform a Delphi inquiry to obtain participants' ideas about objectives or, in this study, the critical factors for effective QE implementation, and to form a hierarchical structure of criteria; 4) conduct another Delphi inquiry to obtain a pair wise comparison matrix for the criteria; and 5) calculate eigen values of the matrix using a software package to calculate priority vectors [13].

In collecting empirical information and data for this study, the authors will consult relevant experts in the field of quality engineering implementation and automotive industry. In the experts consultant step, the Delphi method will be used to obtain the experts judgments in terms of critical success factors (CSFs) model for QE implementation and insights on current status of QE tools and techniques awareness and adoption amongst automotive industries in Malaysia and Indonesia context relating to implementing QE tools and techniques.

IV. OVERVIEW OF DELPHI METHOD

The Delphi technique was developed originally in the early 1950s by Olaf Helmar of the Institute for the Future and Norman Dalkey of the Rand Corporation to estimate the likelihood of the effects of an atomic bombing ([14]; [15]). The Delphi method, despite being a frequently used research technique in fields like medicine or sociology, has not been used very often in the area of knowledge of automotive industries, in general, and in the field of QE studies, in particular (for our knowledge this is the first time that this methodology is used in this field).

The Delphi technique is a method for eliciting and refining judgments from a panel of experts. Consequently, as MacCarthy and Atthirawong [16] point out, it is a systematic process, which attempts to obtain group consensus resulting in much more open and in-depth research, since each member of the group contributes new aspects of the problems to be researched during the post-research phase. This method is carried out by the successive submission of questionnaires, referred to as rounds. Novakowski and Wellar [17] defined round as each of the iterative mail-outs (either by conventional mail or by e-mail) of the survey. Between each round a summary of the results from previous round is communicated to the panel members, and each panel member is given at least one opportunity to re-evaluate his or her original answer based upon the examination of the group response [14]. Rounds continue until stable responses between rounds are achieved.

The Delphi technique may be characterized as a method for structuring a group communication process so that the process is effective in allowing a group of individuals, as a whole, to deal with a complex problem. The main criterion for using the Delphi technique is the indispensability of judgmental information, which may arise in cases where no historical data exist or when such data are inappropriate [14].

Since then Delphi techniques usefulness has been demonstrated in a range of areas outside of defense applications including location decisions in international operations [16]; developing a decision making framework for the total ownership cost management of complex systems in the aerospace industry [18]; investigating the adoption of e-commerce technologies and their impact on business processes [19]; using the Delphi technique in an urban, regional, and ecosystem-based planning context [17]; developing a performance criteria model for school food service [13]; and developing and validating a model that integrates the principles and concepts of TQM with a project-management approach for capital projects in the private sector of industrial construction industry [20].

A Delphi study is a systematic, iterative process to elicit a consensus view from a panel of experts. The approach is often used as a qualitative forecasting technique but is also used to investigate and understand the factors that influence or may influence decision making on a specific issue, topic or problem area [16]. A single opinion may be incorrect, misinformed or tend to a narrow view. In this study, we used Delphi technique to validate the identified critical factors for effective implementation of QE that obtained through extensive literature review and to obtain a pair-wise comparison matrix for the criteria.

The Delphi technique begins with open-ended questionnaire that is given to a panel of selected experts to solicit specific information about a subject or content area. In subsequent rounds of the procedure, participants rate the relative importance of individual items and also make changes to the phrasing or substance of the items ([21]; [22]).

It can be summarized that the first round of the procedure in the Delphi method will allow the individual experts relatively free scope to identify and elaborate on those issues they see as important. These individual factors were then consolidated into a single set. After each of these rounds, responses were analyzed and summarized, which were then presented to the panelists for further consideration. Hence, from the second round onwards, panelists were given the opportunity to alter prior estimates on the basis of the provided feedback. This procedure continued until consensus in the panelist responses was achieved.

The survey was sent out to participants as a word attachment via electronic mail. Respondents were asked to return the survey by e-mail, fax, or postal-mail. There is no clear-cut answer as to how many rounds should be undertaken, but through a series of rounds (typically three) the process is designated to yield consensus ([21]; [23]; and [24]). Although the process of response and reiteration can be repeated as many times as required, Delphi practice has revealed that the rate of response convergence is highest between rounds 1 and 2 [14].

A. Selection of Expert Panel (Participants)

The success of a Delphi study is largely dependent on the quality of the participants (panel of experts) [25]. The nomination of people, who would be appropriate “experts” for this study, was based on the following general criteria:

For Academician:

1. Participants must have a minimum five years experience in conducting research or as a consultant in automotive industries.
2. Research interest in areas of QE, TQM, and statistical quality control tools and techniques.

For Industrial experts:

1. Currently working as General manager/chief executive director, QE/Quality Assurance (QA)/Quality Control (QC) manager in automotive industries (automotive manufacturers or suppliers/vendors).
2. Minimum five years working experience in automotive industries.

The panel nominees were asked to express their expert opinions and judgments on the current status of QE tools and

techniques implementation in their company and to identify the critical factors influencing effectiveness of QE practices. These experts consisted of academician and industrial experts. Initially a personal letter was sent to each of the nominees. The letter invited then to participate in a three-round Delphi study. In addition, the letter included an explanation of the study and provided an estimate of the time commitment for participation.

In the introductory letter, nominees were informed that participation was voluntary and confidential and that three rounds of responses would be required. Nominees were advised that each round of the study would require approximately thirty minutes.

For this research, the Delphi technique was chosen as a suitable preliminary research method because the results will offer a better-informed look at the current and potential status of QE tools and techniques implementation in automotive industries. Towards this end, a set of questionnaire was developed. This survey method allows experts to express their opinion freely and privately. The key feature of the Delphi process is in answering the questionnaire over a number of rounds.

B. Panel Size

Delphi procedures tend to depend on the questions being asked, sample size, and degree of consensus being reached [15]. As this study is a preliminary investigation, the small number of participants was deemed by the researcher to be acceptable for determining a meaningful outcome. The panel size of seven fits within the guidelines recommended for Delphi studies. Helmer and Dalkey used a panel of seven experts in their original Delphi experiment in 1953 [22]. Linstone and Turoff [14] suggests a panel size of anywhere from ten to fifty participants. Brockhaus and Mickelsen (1977, as quoted in [20]) in their survey of prior Delphi method applications found that the recommended number of panel members was primarily a function of four variables: 1) available funding; 2) the topic under study; 3) the number of potential relevant panel members; and 4). The desire of potential panel members to participate.

Thus, a panel of experts was formed to carry out the first round of Delphi method to validate the identified critical factors for effective implementation of QE that obtained through extensive literature review. Participating in the panel of experts (formed in April-December 2008) were seven quality engineering professionals and industrialist from Malaysian and Indonesian automotive industries: quality engineering manager, quality assurance manager, and quality inspection manager from Astra Daihatsu Motor Company Indonesia; QA manager from TRW automotive electronics Malaysia; General manager/executive director of Automotive Industries Sdn. Bhd. Malaysia; Senior general manager of Toyota Motor Manufacturing Indonesia; and specialist of quality engineering from academia, Department of Industrial Engineering, Bandung Institute of Technology. Members of the panel of experts are shown in Table 2.

Table 2 Member of the panel of experts

Name	Position of Expert
B.R.W.	Head of warranty system and quality system department Astra Daihatsu Motor Indonesia
N.W.	Department head of quality engineering Astra Daihatsu Motor Indonesia
H.S.	Head of quality inspection department Astra Daihatsu Motor (ADM) Indonesia
H.A.	QA manager of TRW automotive electronics Malaysia
A.R.N.	Executive director of Automotive industries Sdn. Bhd. Malaysia
I.M.D.	Senior General Manager of Toyota Motor Manufacturing Indonesia (TMMIN) Company
D.I.	Specialist from academia

V. APPLICATION OF DELPHI TECHNIQUE

The Delphi procedure used in this study will consist of three mailed survey rounds. Results of each round will analyze and feed back to the respondents who asked to re-examine their opinions in light of the overall results. The first round survey consisted of open-ended questions designed to elicit expert opinions on CSFs for effective implementation of QE. The first round of Delphi method consists of three sections i.e.: section 1 enquired about general information of the company relating to date of establishment; type of ownership; the approximate number of employee; type of material used to produce product; certified quality system; current position in their company; and which of the quality initiatives implemented. Section 2 enquired the general quality engineering opinions. It is structured around the following questions:

1. What are the quality engineering (QE) tools and techniques that are actually being implemented in automotive industry?
2. What are the benefits and shortcomings of these QE tools and techniques?
3. What are the factors that automotive industries have to consider when selecting QE tools and techniques?
4. What are other factors that affect automotive industries considerations in selecting QE tools and techniques?
5. What are the difficulties faced by automotive industries in adopting QE tools and techniques?

At the end of Section 2, the panel of experts will ask to list all critical factors that most important contributing to effective of QE tools and techniques. The aim of Section 2 is to help us identify the current status of QE tools and techniques awareness and adoption amongst automotive industries in Malaysia and Indonesia and also identify critical success factors (CSFs) for QE implementation. The last section enquired the perceptions of CSFs for QE implementation. In this section all CSFs for effective implementation of QE tools and techniques based on extensive literature review had been identified and developed as the proposed AHP critical factors model as stated in Putri and Yusof [12]. The panel of experts was asked to determine whether they agree with identified CFSs and sub-factors under each CSFs. If they disagree with CSFs and sub-factors under each CSFs, they could make any

adjustment by deleting, moving or modifying CSFs and sub-factors and could write down any comments regarding the proposed CSFs model.

After completion the first round of Delphi method, we summarize responses to the first questionnaire and develop a feedback report. Responses to questions could be grouped or categorized by frequency or other criteria.

The next step of the Delphi method is conducting the second round. For the purpose, we will develop the second questionnaire, mail it to the respondents, and obtain the responses. This questionnaire will develop from the first questionnaire (the first round) responses. Respondents independently evaluate earlier responses based on a feedback report from the initial questionnaire. The aim of the first and second round of Delphi method is to validate the identified critical factors for effective implementation of QE that obtained through extensive literature review.

The third round will be conducted after consensus amongst the panel of experts relating to the CSFs model for effective QE implementation achieved. In the third round of Delphi method, the panel of experts will ask to obtain a pair-wise comparison matrix for the criteria. In this step, the researcher will develop pair wise comparison questionnaire using Saaty's scale (see [10]).

VI. RESULTS AND DISCUSSIONS

Most of the commonly adopted tools in automotive industries according to the panel of experts include customer surveys, failure mode and effect analysis (FMEA), tolerancing that are used in product planning; parameter design as used in product design; process control plan and preliminary process capability studies that are used in process design; feedback, assessment and corrective action as used in product and process validation; meanwhile for production stage, the automotive industries commonly used seven basic tools, seven new tools and process capability studies.

However, it is surprising that some of the tools and techniques investigated in this research study are not adopted to some of automotive industries especially in Indonesia automotive industries. Actually Indonesian automotive industry is essentially an assembly industry, dominated by the major Japanese car manufacturers. Astra Daihatsu Motor (ADM) Company and Toyota Motor Manufacturing Indonesia (TMMIN) Company are the subsidiaries of Astra International Company. Astra International is the major assembler in Indonesia. ADM and TMMIN company are received engineering drawing of product and its specification from their mother company i.e. Astra International Japan. Thus, most of automobile industry in Indonesia did not conduct some of QE stages such as product planning, product design and process design.

It is evident from the findings that many factors influence the adoption of QE tools and techniques. Based on the previous studies as well as the results from the first round of Delphi method, these factors can be classified into internal and external factors. Monetary cost, usefulness, user friendliness (easy to use), time, flexibility and popularity of tools are internal factors which may influence the usage of tools. External factors such as culture, project nature, necessity and organization/industries account for the external influence.

From the findings, the two primary internal considerations are usefulness and user friendliness (easy to use). Time is a secondary internal factor. The remaining two factors, monetary cost and popularity, appear to be less significant to the panel of experts in their decision on tools' adoption. Meanwhile, the two primary external factors are necessity and organization/industries. Project nature is a secondary external consideration. Culture appears to be less significant to the panel of experts in selection of QE tools and techniques. Other factors affecting choice of tools and techniques adopted according to panel of experts are human side; competency and basic skill of user; legal requirements; customer requirements; standard business requirements; risk level; reliability and endurance; benchmarking purposes; direction from mother companies; and training by the external introduces "new" QE tools.

According to panel of experts, there are some benefits of QE tools and techniques i.e.:

1. To find the root cause of the problem.
2. Think of problem solving immediately.
3. To meet customer requirements.
4. To ensure the process of statistical control/control chart is statistically stable and capable.
5. As a tool for continuous improvement.
6. To provide awareness on quality status.
7. Visibility.
8. Traceability.
9. Quality performance trend.
10. Quality conscious minded.
11. To support smooth regular quality activity.
12. To eliminate previous problem.
13. To improve the existing product or process.

Many authors agree that the use and selection of quality management tools and techniques are vital to support and develop the quality improvement process [26]. However, companies, in this case automotive industries, do encounter a range of difficulties in their use and application of quality engineering tools and techniques. The findings from the first round of Delphi method indicate that there are some difficulties faced by automotive industries in adopting QE tools and techniques i.e.:

1. Lack of knowledge about the tools.
2. Poor measurement system and data handling.
3. Sense of quality of operator still low.
4. Lack of management commitment.
5. Lack of statistical knowledge.
6. Lack of understanding of the potential benefits of the tools.
7. Lack of education and training.
8. Lack of resources.
9. Poor attitude towards quality improvement.
10. Lack of team work and cooperation.
11. Lack of communication.
12. Lack of awareness of tools and techniques available.
13. Lack of quality system.

Most of expert panel stated that lack of knowledge about the tools; poor measurement system and data handling; lack of statistical knowledge; and lack of management commitment are the primary difficulties faced by automotive industries in adopting QE tools and techniques. It is evident

that many of the tools and techniques to be used in the QE stages require a sound basis of training and education in terms of statistical knowledge. By identifying the critical factors that make for effective use of QE tools and techniques, the results from the first round of Delphi method could be useful for developing the established AHP model for QE tools and techniques implementation.

VII. CONCLUSIONS AND FURTHER RESEARCH

The use of QE tools and techniques is a vital component of any successful quality improvement process. The application of these tools and techniques at the specialty automotive industries demonstrates the many difficulties that can be experienced when trying to apply them. The findings from the first round confirm the CSFs for effective and successful QE tools and techniques are really needed to support continuous improvement process.

This paper attempted to pinpoint areas lacking in implementation of QE tools and techniques and difficulties faced by company relating to QE practices. By conducting the first round of Delphi method, we were able to collect experts' opinion in term of critical factors contributing to effective QE tools and techniques.

Further research will centre on conducting the next steps of Delphi method i.e. the second and third round. The purpose of the second round is to obtain agreement from the panel of experts on the hierarchy structure of the critical factors obtained from the analysis of the first round. Finally, in the third round, we will develop a pair wise comparison questionnaire of the critical factors identified in the Delphi process. It will be used to collect pair wise comparison data. Pair wise comparison that used in the AHP process intent on comparing the relative importance criteria and sub criteria in all possible pairs. By the pair wise comparison data, we can obtain the priority and ranking of each criteria and sub criteria in terms of effective and successful QE tools and techniques implementation. It is hoped that the results will create much clearer understanding of these critical factors and benefit both countries in the quest for quality engineering excellence in the automotive industry.

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